# A KINEMATIC ANALYSIS OF FINGER MOTION IN ARCHERY


**Brian Horsak, Mario Heller, Arnold Baca**

**Department of Biomechanics, Kinesiology and Applied Computer Science, Centre of Sports Sciences and University Sports, University of Vienna, Vienna, Austria**



This paper examines finger motion during the bow string release in archery. METHOD: Fifty-six shots from one athlete were captured with an infrared motion tracking system. Kinematics for index, third and ring fingers were calculated. Two different kinematic variables were defined, related to the proximal interphalangeal joint (PIP) of the third finger: maximum angular velocity (MAX) and minimum angular velocity (MIN). For statistical analysis shots were separated into two groups (very good shots: shots which hit the innermost score area and bad shots: score of 8 or less; shots which achieved a nine or a ten were excluded). A Mann-Whitney test was used. RESULTS: No significant differences were found in the variables MAX and MIN between very good and bad shots ($p > 0.05$). CONCLUSION: Findings in this study show that there are no significant differences in angular velocity (related to the PIP joint) between very good and bad shots, but that reproducibility of kinematic characteristics are possible crucial factors in archer's performance.



**KEY WORDS:** motion analysis, release, bow, finger joints


## INTRODUCTION:

Coaches in archery often pay a lot of attention to the release phase of the shot. To avoid lateral deflection, the release phase of the fingers must be well balanced and highly reproducible (Ertan et al., 2003; Leroyer et al., 1993; Martin et al., 1990; Soylu et al., 2006). For investigation of finger movement several authors used surface EMG for analysing muscular activity, muscular coordination and different types of release strategies (Ertan et al., 2003; Martin et al., 1990 and Soylu et al., 2006). However, none of the investigations focused on the finger motion itself in its three-dimensional aspects. In the past few years motion analyses of finger and hand motion have gained large attention (e.g. Cerveri et al., 2007). Due to the relatively new opportunity of using motion capturing systems in hand motion analysis and due to the fact, that there has been hardly any three-dimensional kinematic research of finger motion in archery, this paper is going to demonstrate how an optoelectrical system can be used for three-dimensional analysis of the finger motion during the bow string release in Olympic recurve archery. The finger movement of a participant was analysed due to specific kinematic parameters. Statistical analyses were performed to investigate if there are any significant differences in selected kinematic values between "very good" and "bad" shots.

## METHOD:

**Data Collection:** A motion tracking system (Vicon Motion Systems Limited, Oxford, UK) was used for analysis. The system consisted of eight infrared cameras (six cameras with a resolution of 1.3 Mega Pixels, and two cameras with a resolution of 4.0 Mega Pixels), an acquisition station system (Vicon MX Net) connected to a personal computer and 3D reconstruction software (Vicon Nexus 1.2 and BodyBuilder 3.6). Data were collected with 500 Hz. System accuracy was tested by tracking two markers mounted on a rigid object. Marker distance yielded differences in length of less than 0.2 mm. B-spline approximation was used for interpolation (2000 Hz) and differentiation. Kinematics in the finger joints were calculated using the VICON right hand model. This kinematic model calculated flexion/extension and abduction/adduction for all fingers (using the technique of Cheng & Pearcy, 1999) of the right hand and was programmed for BodyBuilder 3.6. A majority of competitive archers shoots using the three finger grip release. The finger release is defined as the point on which the bow string slips off from the finger tips. Due to this fact analysis in this paper was focussing on the three finger grip which included index, third and ring fingers. Semicircular markers with a diameter of 9mm were used and positioned on bony landmarks on the archer's right hand (Figure 1). The marker positions were based on the VICON right hand model: The investigated participant was a competitive archer from the Austrian B-National Team (age = 49 years, best FITA Indoor score = 1131 out of 1200 points) who took part in several national and international competitions (e.g. World Games 2007). Prior to participation, the subject read and signed a consent form, which was approved by Institutional Review Board at the Centre of Sport Science and University Sport of Vienna. The subject participated in three test sessions (one session included 30 shots, ten times three shots) in the Biomechanics Laboratory at the University of Vienna. Thirty shots at a distance of 18 meters (a FITA Indoor 40 cm vertical triple target face was used) were captured in one session. In sum, ninety shots were captured out of which, due to marker occlusion, fifty-six shots could be used for further analysis.

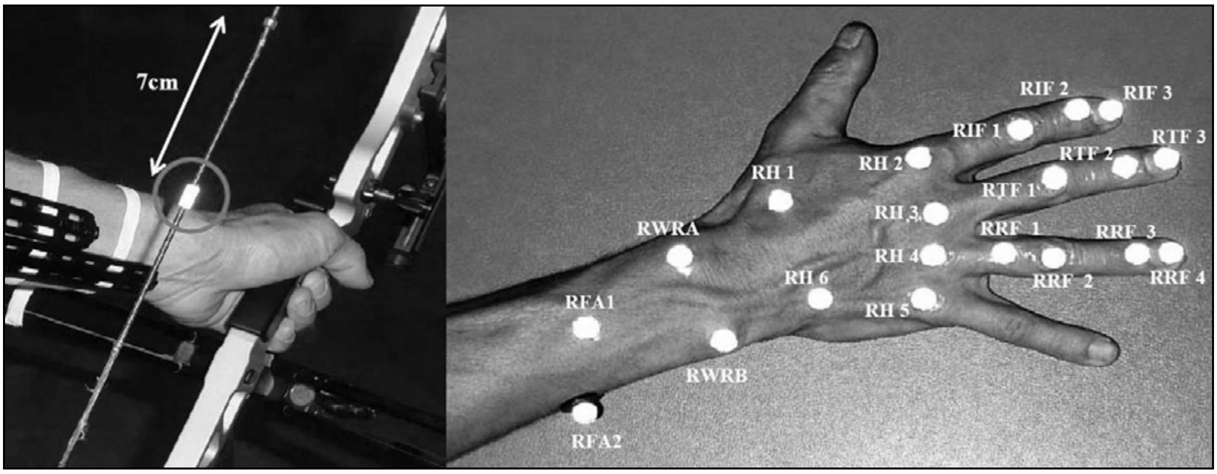

**Figure 1: Marker placement for the bow string and the right hand.**

**Data Analysis:** Analogue as performed in Keast & Elliot (1990) shots were corresponding to their achieved score separated into two groups: very good (score of x; x is the innermost score area of the target face) and bad (score of 8 or less) shots; shots which achieved a nine or a ten were excluded. Two different kinematic variables were defined (related to the PIP joint of the third finger): maximum (MAX) and minimum (MIN) angular velocity during the release of the bow-string (Figure 2). A Mann-Whitney test was used for statistical analysis.

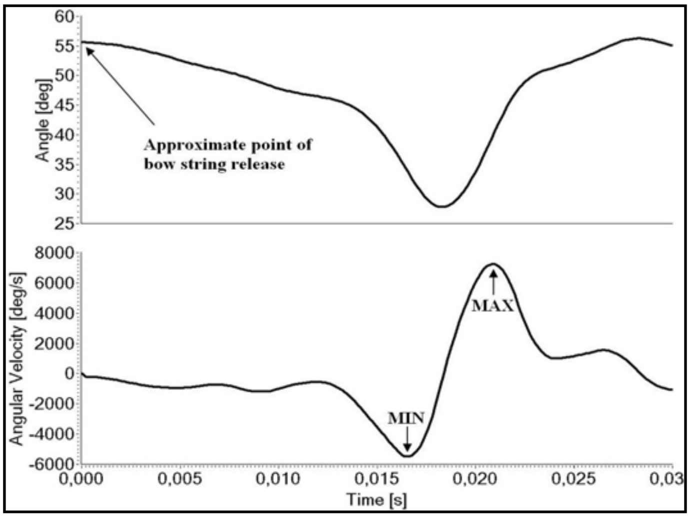

**Figure 2: Kinematic variables: maximum (MAX) and minimum (MIN) angular velocity during the release of the bow-string (related to the PIP joint of the third finger).**

For each shot, the ranges of motion of the metacarpophalangeal (MCP), proximal interphalangeal (PIP) and distal interphalangeal (DIP) joints during the shot itself were measured. The range of motion of each finger (FROM) was defined as the sum of ranges of motion of its three joints (JROM). The range of motion of each joint was then expressed as a percentage of the corresponding finger's range of motion (PCROM).

**RESULTS:** A Mann-Whitney test was used for analysis considering $p < 0.05$ to be significant. As values in Table 1 show, no significant differences were found.

**Table 1 Descriptive statistics for very good and bad shots and results for statistic analysis (Mann-Whitney test for very good and bad shots).**

| Bad shots | | | Very good shots | | |
|---|---|---|---|---|---|
| | MAX [°/s] | MIN [°/s] | | MAX [°/s] | MIN [°/s] |
| Mean | 687 | -5123 | Mean | 6923 | -4558 |
| ± SD | 743 | 810 | ± SD | 1063 | 443 |
| Minimum | 5675 | -6394 | Minimum | 5495 | -5193 |
| Maximum | 7895 | -3943 | Maximum | 8392 | -3656 |
| | *p*-value for MAX | *p*-value for MIN | | | |
| Mann-Whitney t. | *0.870* | *0.221* | | | |

Table 2 shows analysis for ranges of motion for all three fingers and appending joints. In sum the index finger achieved the highest value of FROM with 81 ± 5°. Most active joint was the DIP joint for the index finger (42 ± 5°), the PIP joint (32 ± 2°) for the third finger and the DIP joint (28 ± 4°) for the ring finger. Least movement was performed in the MCP joints (all fingers). The DIP joint showed a majority in PCROM for the index and ring finger (52 ± 6 and 57 ± 9 %). The PIP joint achieved a major PCROM for the third finger (55 ± 4 %).

**Table 2 Results for range of motion analysis during the shot.**

| | FROM [°] | | |
|---|---|---|---|
| Index finger | *81 ± 5* | | |
| Third finger | *58 ± 3* | | |
| Ring finger | *48 ± 5* | | |
| | JROM [°] | | |
| | MCP | PIP | DIP |
| Index finger | *9 ± 28* | *30 ± 2* | *42 ± 5* |
| Third finger | *7 ± 2* | *32 ± 2* | *19 ± 2* |
| Ring finger | *6 ± 2* | *15 ± 2* | *28 ± 4* |
| | PCROM [%] | | |
| | MCP | PIP | DIP |
| Index finger | *11 ± 2* | *37 ± 3* | *52 ± 6* |
| Third finger | *12 ± 3* | *55 ± 4* | *33 ± 4* |
| Ring finger | *13 ± 3* | *30 ± 5* | *57 ± 9* |

*Note.* FROM = range of motion of each finger; JROM = range of motion of each joint; PCROM = percent of the corresponding finger's range of motion.

**DISCUSSION:** No significant differences were found for the variables MAX and MIN (note that correlations between performance and variables, which were calculated in addition, showed no significant values, also). One possible reason might be numerical problems due to low accuracy of the second derivatives. Results for ranges of motion showed that especially the PIP and DIP joints are highly involved in the finger release. Least JROM was quantified for the MCP joints. Analysing the range of motion for each joint in respect to the range of motion for each finger (PCROM) the DIP joints showed highest values for the index and ring fingers. For the third finger the PIP joint showed the highest percentage of PCROM. Kinematic characteristics let presume that reproducibility is a possible crucial factor in archer's performance. Figure 3 and 4 show path-time diagrams of the MCP, PIP and DIP joints of the third finger. Three randomly selected shots out of the very good and bad group are exemplarily plotted. As it can be seen, the peak minimum values in both groups are almost similar for all three shots, but the characteristics of the graph before and after their minimum peak show hardly any differences for the "very good shots" and clearly more differences for the “bad shots”. These findings probably support the assumption of Edelmann-Nusser (2005) that the motoric programme of arrow release in the manner of an open-loop movement is already initiated before clicker’s fall.

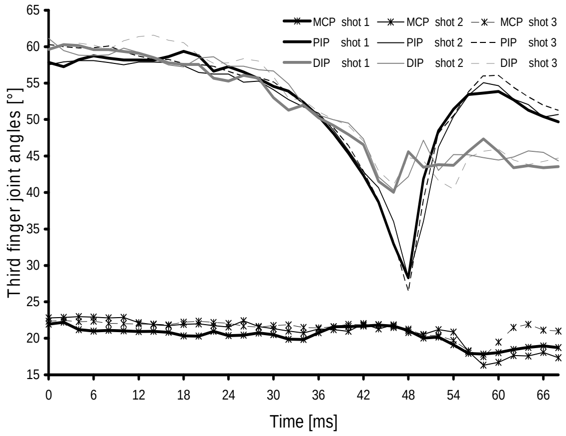


**Figure 3: Time-path diagram of three randomly selected shots: "very good shots" (time-synchronized over minimum PIP peak).**

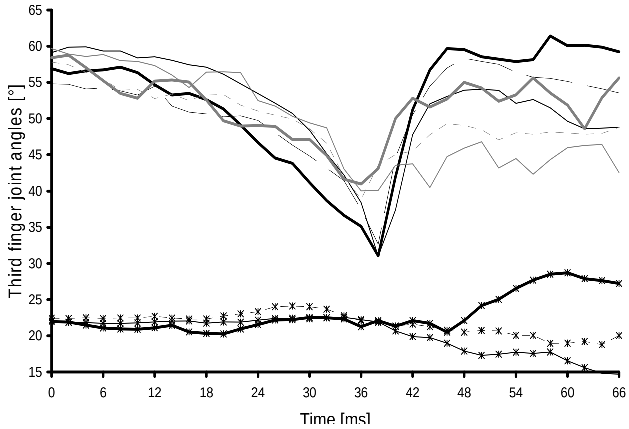


**Figure 4: Time-path diagram of three randomly selected shots: "bad shots" (time-synchronized over minimum PIP peak).**

**CONCLUSION:** A measuring setup for three-dimensional motion analysis of hand motion in archery was developed and it was shown, that modern tracking systems can be used for research in finger motion analysis in archery. Time-path diagrams for kinematic data showed similar parameter values and graph-characteristics throughout the movement for “very good shots” and less similarity in graph-characteristics for “bad shots”. These findings should be further investigated with a higher number of subjects.

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